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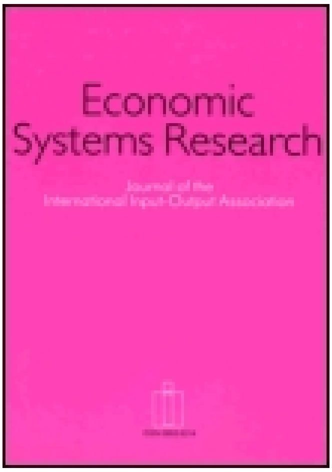

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INPUT–OUTPUT ANALYSIS: THE NEXT 25 YEARS

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This year marks the 25th anniversary of the International Input–Output Association and the 25th volume of *Economic Systems Research*. To celebrate this anniversary, a group of eight experts provide their views on the future of input–output. Looking forward, they foresee progress in terms of data collections, methods, theory testing, and focus and scope.

Keywords: Input–output tables; Interindustry analysis; Global applications; Environmental extensions; Trade

1. INTRODUCTION

The International Input–Output Association (IIOA) was founded in 1988 and in the same year the first issue of *Economic Systems Research* (*ESR*) was prepared. This implies that both the association and the journal are celebrating their 25th anniversary in 2013. Although 1988 marks the launch year of the IIOA, the preparations had been going on for some time. Just as a matter of fact, the decision to set up an association was taken at the Sapporo conference in 1986. And, of course, a lot had happened in input–output (I–O) before 1988. For example, the first international I–O conference already took place in 1950 and Leontief received the Nobel Prize in economics in 1973 (see Appendix C5 in Miller and Blair, 2009, for a brief historical account). For an excellent overview of the field in 1988, see the paper "Input–Output Analysis: The First Fifty Years" by Rose and Miernyk (1989), the title of which we have paraphrased for the occasion.

To celebrate our anniversary, we would like to look forward – rather than to look backward – in a hopefully festive paper. If only to make some of our – now – young readers smile in 2038 about so much ignorance today. The current president of the IIOA (Erik Dietzenbacher) and the current editors (Manfred Lenzen and Bart Los) have taken the initiative to invite a group of scholars (young and old, with a spread over the sub-fields) to submit their views on the future of input–output analysis (IOA). In terms of contents and style,

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there were no restrictions. The rest of this paper presents the individual pieces of text as separate sections.

2. THE VIEWS OF ERIK DIETZENBACHER: ABOUT WINE AND BOTTLES

2.1. Introduction

In a splendid paper, Quoidbach et al. (2013) report on a set of experiments they have carried out. They asked more than 19,000 people, ranging in age from 18 to 68, how much they had changed in the past decade and how much they expected to change in the next decade. Irrespective of their age, they all believed that they had changed a lot in the past but would not change much anymore in the future. The authors termed this the “end of history illusion”, i.e. after drastic changes in the past, people think that they have finally become who they will be for the rest of their lives.

My own feeling is that this illusion goes beyond one’s personal life. At least for me, it also applies when trying to think about the future of I–O. I expect a lot of old wine in new bottles, with very little new wine. Two immediate remarks seem in place though. First, nothing is wrong with old wine in new bottles, as long as the wine tastes fine. Second, recall that my outlook is just an illusion.

In the future developments of I–O, I see two broad areas. These are: exploiting sources of information and sensitivity analyses.

2.2. Exploiting Sources of Information

An important aspect of our research in the past has been the linking of input–output tables (IOTs) to all sorts of other information. With the improvement of the quality and, in particular, the availability of data (also for developing countries), I expect to see an enormous growth in this area. In this respect, I want to distinguish three lines of development.

First, the construction of global multi-regional input–output (MRIO) tables. In the last couple of years, various groups of researchers have constructed such tables. Although the idea is far from new, it has only recently become possible to construct such tables (see Tukker and Dietzenbacher, 2013, for an overview). I expect that the work on global MRIO tables will intensify: more detail in terms of products and industries, in terms of countries, and the splitting of one (or some) of the countries in the global MRIO table into regions (see, e.g. Feng et al., 2013). A further step is to take states, provinces, counties, or neighborhoods (instead of countries) as the “regions” in global MRIO tables.

Second, the typical Isard-type interregional IOT lists the same set of industries in different regions within a country. Similar national tables have been derived with a distinction between different types of production (instead of regions). For example, Dietzenbacher et al. (2012) have used tables for China distinguishing for any industry (e.g. Telecommunication equipment, computer, and other electronic equipment) whether its production is for domestic use only, whether it is for processing exports, or whether it is other production (see also Koopman et al., 2012). In a similar vein, tables have been constructed for Japan (Ogawa et al., 2012) reflecting for each industry the production of the small-sized and the large-sized firms in that industry.

Third, IOTs have always been appended by satellite accounts using the same industry classification. Examples are employment data for many occupations, R&D expenditures, all sorts of emissions, the use of energy, water, and land. Recently, IOTs have been linked to other types of data such as biodiversity (Lenzen et al., 2012) and one of my own students analyzed how many deaths in the USA were due to Chinese consumption and vice versa (Vargas, 2012). I expect that IOTs will be linked in the future to a wide variety of data sources, such as engineering data, data from geographic informations systems (GISs), data from microsurveys at the firm level, or household surveys.

It should be stressed that the three lines of development as sketched above will be intertwined. For example, data on water use show that consumption of beef requires approximately three times as much water as the same amount of pork does. To take this difference into full account calls for detail, i.e. an IOT that distinguishes between the production of beef and of pork. In the same vein, some resources (for example, scarce metals) are only extracted at a few locations. To enable a thorough analysis, all such locations (i.e. countries) should be included separately in a global MRIO table, which holds even if the country is (economically) very small. In addition, one might want to use a global *physical* MRIO table.

2.3. Sensitivity Analyses

The increased availability of data sources implies that the linking of data will increase and that for some cases more than one data set is available. Much of the future work in I–O will involve estimation (which – depending on the type of application – is also termed as projection, interpolation, or imputation). This means that the information contained in the IOTs and satellite accounts that we are working with is uncertain. The question arises therefore how confident we can be of the results. This requires sensitivity analyses.

Some data construction work requires assumptions, and it is thus relevant to know how sensitive the outcomes of the calculations are to the assumptions. That is, do different assumptions change the outcomes very much or not? The same applies for projections, where it is important to investigate how the outcomes differ for alternative scenarios (i.e. assumptions for the exogenous variables). In the same vein, it is interesting to know whether and to what extent the results differ across data sources (for example, global MRIO tables or CO_2 emissions). I expect that we will see many of such sensitivity analyses (or comparisons across alternative assumptions, scenarios, and data sets) in the future.

These analyses point at a very fundamental question. In the World Input–Output Database (WIOD) project, we devoted one of the work packages to examining this fundamental question, namely whether the construction of the WIOD tables was worth all the money funded by the European Union (EU). (It should be stressed that it was formulated somewhat – but not much – different.) Of course, when we raised the question we already knew the answer. That is, for some questions one needs a global MRIO table, for some questions not. I expect that one of the future tasks is to come up with a catalogue or categorization of what data are required for what problems? Put in another way, what outcomes can be obtained reliably through shortcuts? To give a small example from the work in the WIOD project, Dietzenbacher and Temurshoev (2012) analyzed the effect of an exogenous shock in the final demand in current prices on the gross outputs in constant prices. They found that for this question it was not necessary to construct an IOT in constant prices, deflating the outcome in current prices yields almost the same answer.

FIGURE 1. A non-linear IOT.

2.4. Final Remarks

Next to the developments above, which are extrapolations of recent work and the consequences thereof (i.e. old wine in new bottles), there will also be developments that I cannot foresee (i.e. new wine). Typically, I expect them to come from outside the I–O community. Interesting research has been done recently in terms of testing theory, using I–O tables and analyses as tools. The most prominent series of papers focus on trade theory and trade in value-added in particular. Triggered by the concepts of international fragmentation, global supply chains, and slicing up the value chain, several papers have been published on this topic (Trefler and Zhu, 2010; Bems et al., 2011; Johnson and Noguera, 2012; Koopman et al., 2013). And again, there is a lot of old wine in new bottles. Recall that Leontief (1953) was the first to empirically test the Heckscher–Ohlin theory. Also, a lot of the recent calculations have been done in the past. But in those days we were just interested in interdependencies and backward and forward linkages between countries (see Dietzenbacher and van der Linden, 1997), global value chains were not an issue then. This emphasizes that it is the question, the problem, that is new and exciting, not so much the methodology.

I very much hope that also other researchers (next to those working on trade) will discover I–O tables and analyses as a fruitful tool to answer their question. The signs are positive, given recent work published in top journals by Holz (2011), Acemoglu et al. (2012), and Antràs et al. (2012).

Last year at the I–O conference in Bratislava, I briefly – and jokingly – talked about my own future, i.e. my life after the WIOD project. Referring to my earlier mathematical work on non-linear I–O analysis (Dietzenbacher, 1994), I proposed that things would be much easier by using non-linear IOTs (see Figure 1). Who knows? I guess it might be an example of new wine in an old bottle.

3. THE VIEWS OF MANFRED LENZEN: 2038, OR: THE BRAVE NEW WORLD OF I–O

It is 2038. A new System of Environmental Accounts – the SEA 2038 – has just been released. It replaces previous arrangements, chiefly by understanding that the world simply as one environment within which transfers of value, mass, and human capital seamlessly integrate. The journey to this success was a long and arduous one, and involved progress on multiple fronts: technological, computational, and financial. One of the toughest challenges was to overcome communication barriers and achieve consensus between dissenting groups of individuals. This essay tells the story of this journey.

2016 – The Project Réunion consortium successfully launches the Global MRIO Virtual Laboratory. The Virtual Lab connects researchers to joint multi-disciplinary research facilities where they share data repositories and computational tools, thus enabling more collaborative research, and improved research efficiencies. Previously disparate MRIO research workflows are streamlined, compilation pipelines fully automated, and new opportunities for I–O innovation emerge.

2017 – The United Nations (UN) initiate talks with the Global Reporting–Initiative, the Carbon Disclosure Project (CDP), the Greenhouse Gas Protocol, and the Life Cycle Initiative (a joint organisation of UNEP, the United Nations Environment Programme, and SETAC, the Society for Environmetal Toxicology and Chemistry) on harmonizing and aligning the various product and corporate, environmental, footprint, and life-cycle reporting standards. Under pressure by mostly developed nations opposed to MRIO-supported consumption-based emissions accounting, the Intergovernmental Panel on Climate Change (IPCC) hesitates to join the negotiations.

2019 – The UN, OECD, and EC statistical offices combine into WorldStat. In its first outreach effort, WorldStat convenes a series of international talks on harmonization of data, classifications, and accounting standards amongst statistical agencies across the world. Numerous concordance libraries are established, bridging previously disparate accounting systems. Gradually, national statistical offices join WorldStat.

2021 – WorldStat purchases its first high-performance-computing (HPC) petabyte-RAM cluster in order to pave the way for the large-scale integration of global process and business data, and a centralized, globally governed implementation of a World MRIO Virtual Lab.

2023 – WorldStat combines the Systems of National Accounts (SNA) and System of Environmental Economic Accounting (SEEA) guidelines into one framework – the WorldStat System of National and Environmental Accounts SNEA 2023 – and stipulates that from then on only one document would be issued. In the new SNEA, the term “environment” is understood as including notions of the natural-living, abiotic-resource, and human–social–psychological environment. WorldStat’s environmental satellites feature a routine list of accounts on the land–water–climate–toxicity–biodiversity–nexus, the status of more than one million naturally occurring and fabricated resource compounds, and characteristics of the global society such as skills, inequality, child labor, education, armed conflict, innovation, women’s workforce participation, occupational health and safety, and subjective well-being. Most of the world’s nations have followed Bhutan’s lead in establishing policy that maximizes gross national happiness. The measurement of gross domestic product (GDP) is slowly being phased out.

2026 – In the aftermath of the first ice-free summer arctic, and following massive meltdown seasons in Greenland, the IPCC, bogged down by persistent carbon leakage thwarting lasting emissions mitigation, and encouraged by WorldStat’s successes in compiling and maintaining robust time series of global MRIO systems, finally agrees to implement consumer-based emissions principles worldwide. WorldStat is entrusted with the oversight of the global greenhouse gas (GHG) emissions reporting system.

2029 – For the first time, WorldStat integrates GIS principles with MRIO accounting. WorldStat's new 64-petabyte-RAM hardware supports continuous time series of GIS-coded global MRIO frameworks at very high regional detail. Negotiations are initiated with producers worldwide to implement GIS-tagging of transactions.

2032 – WorldStat introduces its new product classification, the massive-dynamic harmonized system (MDHS). The MDHS replaces all previous classifications such as the UN Harmonized System, the ISIC, SITC, etc. Moreover, it makes classification revisions redundant, because of a new innovation – dynamic class posts (DCPs). This innovation effectively responds to the inability of previous classification systems to cope with the rapidly ever-increasing product diversity and by-production complexity. Using DCPs, any producer can launch a real-time request for adding a new MDHS product code along with its WorldStat patent ID. WorldStat's super-cluster's search-bots then prompts a match-attempt that, if unsuccessful, allows the new code to pass and integrate immediately. The MDHS also does away with the old concept of 'industry', given previous futile efforts of grouping modern multi-function, auto-adjusting production pipelines into rigid categories.

2033 – WorldStat upgrades their HPC systems to include for the first time an exabyte-RAM super-cluster called 'HAL'.

2036 – As a result of the introduction of HAL, world currencies are abandoned, and 99% of world value flows in electronic form. Modern surface teller chips – transparent non-toxic nanolayers sputtered directly onto products – are recognized in staff-less, geographically mobile product outlets, linking every transaction in the world to WorldStat's HAL in real-time, tagged with information on the product's value, environmental-resource-societal satellite attributes, MDHS code, GIS code of the point of transaction, as well as seller and buyer ID. This information is constantly integrated by HAL's Ω-RAS engine into I–O-hypercubes (IOHCs). IOHCs are poised to replace the outdated MRIOs by abandoning the fixation on classifications, regions, and annual cycles.

2037 – WorldStat embarks on drafting a new SEA 2038 to replace the SNEA 2023. The SEA 2038 abandons the idea of national responsibility for account compilation, mandates dynamic GIS and MDHS classification procedures, and sets in stone the establishment of IOHC as the new generation of global information systems.

4. THE VIEWS OF BART LOS: I–O UNCHAINED?

Over the past 25 years, the field of I–O analysis has gone through hard times. I feel it has only survived due to its popularity in environmental sciences, since it lost a lot of its appeal in the economics profession. Below, I will argue that the field might very well be much more popular among economists again in the next 10 (if not 25) years, provided that I–O practitioners pay more attention to developments in other fields of economics than they used to do in past decades.

I–O researchers have often analyzed changes in 'vertically integrated industries'. These can loosely be defined as all activities involved in the production of a unit of product delivered to final demand. The concept was developed extensively by Pasinetti (1973, 1981). Wolff (1985) and Dietzenbacher et al. (2000) explicitly referred to the concept in empirical productivity analyses based on IOTs. For a long time, mainstream economists viewed the study of vertically integrated industries as an exotic activity. This has changed dramatically with the recent global unbundling of production stages for final products

(Baldwin, 2006). Suddenly, I–O's somewhat peculiar vertically integrated industries have turned into hotly debated 'global supply chains'. The performance of industries, regions, and countries has become increasingly dependent on the extent to which they manage to participate in global supply chains for products assembled in a different country. Initially, case studies provided micro-insights (see, e.g. Sturgeon et al., 2008). Whereas IOTs and associated models have for long been considered as a sometimes unnecessarily detailed way to describe national economies, the global unbundling of production stages will make IOTs indispensable for policy-relevant empirical macroeconomic analyses. The recent availability of a number of global I–O databases (see, e.g. Andrew and Peters, 2013; Dietzenbacher et al., 2013; Lenzen et al., 2013; Tukker et al., 2013) thus carry a lot of promise for macroeconomic studies of the impacts of global value chain participation.

The production of global I–O databases will not be sufficient for a return of I–O to the forefront of economics, though. New I–O techniques specifically geared towards the study of global supply chains should be devised. Let us take the example of carbon emissions. Traditionally, decreasing emissions per unit of gross output in Country A were considered to be evidence of technological progress in that country. In a chained world, this is not necessarily a correct interpretation anymore. Advances in information and communication technology enable firms headquartered in Country A to relocate carbon emissions-intensive production stages to Country B. In this situation, the consequent reduction in A's carbon emissions coefficient is not due to technological progress, but to changes in trade patterns. This implies that I–O researchers should come up with new types of structural decomposition analyses to isolate the causes of national territorial changes in carbon emissions, since the emergence of global value chains has rendered traditional decompositions misleading.

Another issue arising with the increased unbundling of stages of production of final products is the reduced relevance of comparisons of primary input coefficients between countries. In 'Jorgensonian' productivity studies (e.g. Jorgenson et al., 1987), productivity levels for, e.g. the transport equipment industry are compared across countries. In its basic form, this is done by relating industry gross output to quantities of factor services and intermediate input use in the industry, for each country concerned. With continued globalization, analyses like these become less relevant. The Thai car manufacturing industry produces standardized motor vehicle parts and components, while its US counterpart manufactures consumer-tailored final products (see Sturgeon et al., 2008). Comparing productivity levels of such activities is like comparing apples and oranges. Instead, I–O researchers and productivity scholars could together make great strides by devising schemes that allow for analyzing productivity growth within global supply chains and differences across chains. This requires a framework in which production factors in different countries and industries can act as substitutes for each other (Baldwin, 2013). Such an approach will be much more fruitful in providing insights into the drivers of productivity growth than more traditional analyses for national industries.

The degree to which these promises for I–O will materialize will, in my view, be determined by two 'success' factors. First, much has still to be gained in terms of data. I will just mention two issues here. International trade in services is becoming more and more important, but is still poorly covered in official statistics. The problematic quality of these data directly feeds into the reliability of the global IOTs. The other constraint relates to the fact that exporting firms tend to use production technologies that are different from non-exporters, see Chen et al. (2012) (modern trade theory à la Melitz, 2003, is actually based on this fact). Such differences are largely neglected in the data on which the current global I–O databases are built. Hopefully, researchers can convince international statistical agencies of the importance of improvements in these respects.

The second success factor relates to the attitude of the community of I–O researchers. With hindsight, too many economics-oriented I–O scholars have not tried enough to link up to tendencies in other fields in economics. This is reflected by the fact that the first influential economic applications of global IOTs were published by authors without a strong record in I–O analysis, such as Trefler and Zhu (2010), Johnson and Noguera (2012), and Koopman et al. (2013). Hence, I do not agree with Baldwin's (2013) statement that I–O scholars have become 'rock stars' as a consequence of globalization. By constructing nice datasets, they have just shown to be very good 'roadies', the hard-working but unknown people who prepare the stage for the stars… I hope to have shown that it is not too late, however. If cooperation with economists in more generally recognized fields is actively sought, I–O researchers can contribute to substantial steps forward, by analyzing the good old vertically integrated industries in the context of globalization issues, thereby riding high waves in economics research in the next one or two decades. So, let us link up much more with other economists to benefit from the emergence of global value chains, or, to paraphrase rock star Joe Cocker, let us 'Unchain I–O, Set It Free!'.

5. THE VIEWS OF DABO GUAN: MRIO LED BY DEVELOPING COUNTRIES WITH A GLOBAL CITIES FOCUS

The recent developments of global MRIO models (e.g. Peters et al., 2011; Lenzen et al., 2012; Dietzenbacher et al., 2013; Tukker et al., 2013; see Tukker and Dietzenbacher, 2013, for an overview) have drawn great interests from the academics and started to influence political strategies in tackling global environmental challenges. MRIO models are good tools to study regional homogeneity and heterogeneity in terms of economic developments, cooperation (via trade or technological transfers), and environmental implications. Wiedmann (2009) and Peters et al. (2012) provided good reviews about MRIO models. The essential factors in successful construction and development of national I–O accounts and global MRIO tools consist of comprehensive and reliable official statistics (Tukker et al., 2009), collaborative efforts from the whole I–O community, and national and international funding provided. Those factors often lack in developing countries and at the city level. The future of I–O analysis can be led by developing countries and MRIO approaches can be extended to have a global cities focus.

5.1. MRIO Models Within Emerging Economies

Regional heterogeneity exists within country borders (Shankar and Shah, 2003). Those emerging economies, such as Brazil, Russia, India, China, and South Africa (BRICS), are characterized with strong subnational inequalities and interdependencies (Bhattacharya and Mahalanobis, 1967; Jian et al., 1996; Azzoni, 2001; Fedorov, 2002). The inequalities include geophysical conditions, resources availabilities, socioeconomic developments, and technological levels. The regional interdependencies are usually associated with trade and policy coordination. In principle, these challenges can be analyzed and solutions can be identified and examined by using an MRIO framework. Due to the dynamics of BRICS's economies, cross-regions policy decision-making and coordination can be improved with reliable quantitative evidence derived from multi-regional analysis. However, the current status of subnational analyses mostly stays at a signal region's level. The development of MRIO models to capture interregional linkages within a country is still rare. The two key difficulties in constructing such models are a lack of interregional trade records and insufficient funding interests from the funding bodies. Bilateral or multi-lateral trade between countries can be obtained in global trade statistics from world organizations (e.g. World Trade Organization (WTO), the United Nations (UN), Food and Agriculture Organization (FAO)) or countries' custom data. There are often no statistics to specifically record subnational trade, except at the firm level. In order to tackle the data issue, I–O researchers have utilized some 'proxies' (e.g. transportations between regions) and developed a set of mathematical techniques (e.g. the gravity model and the location quotient) to estimate subnational trade flows (see Miller and Blair, 2009). Some earlier attempts of interregional models are summarized by Oosterhaven (1984). In recent years, some more efforts have been made to improve the gravity model or using location quotients to construct subnational MRIO models for countries like the USA (see Rickman and Schwer, 1995), UK (e.g. Barker and Peterson, 1987; Barker et al., 2007; Yu et al., 2010), and China (e.g. Liang et al., 2007; Feng et al., 2012, 2013; Meng et al., 2013). Future research is required to further improve the quality of techniques applied in estimating trade flows in subnational MRIO models in those emerging economies.

Further, large consumption inequalities often occur between population groups (Deaton and Paxson, 1997) within any emerging economy. China's IOTs and its provincial tables have managed to separate the households' final demand between 'urban' and 'rural'. Further disaggregation of household types in terms of income or consumption categories can be made. Together with development of a 'social accounting matrix' (SAM) for developing countries or regions can be useful to produce quantitative evidence to identify true contributors to local and global environmental crises. Future research is required to integrate household disaggregation into MRIO models so as to combat regional and cross-regional socioeconomic and environmental inequalities.

5.2. Global Cities I–O Database

Cities are large drivers of national GDP, energy consumption, emissions, and main centers of innovation. There are 3.6 billion people (54% of the world's total) living in urban areas in 2011, which will increase to 6.3 billion (70%) in 2050 (United Nations, 2012). Cities account for 60–80% of world economic activities and energy consumption, and for 75% of carbon emissions. There are 8 Chinese and Indian cities among the list of top 20 cities with the highest loss in coastal flooding in 2050 (Hallegatte et al., 2013). Understanding city development has a long history in economics and regional science. But for decades, urban economic research focused on individual cities. Many city-specific environmental analyses have been conducted by using environmental extended I–O analysis. Some examples are to study energy consumption (Lenzen et al., 2004), CO_2 emissions (e.g. Chong et al., 2012; Liu et al., 2012), water consumption and pollution (e.g. Zhang et al., 2011) and so on. But research on linkages and interdependencies between global cities and their environmental implications are rare. The unsolved and possibly more interesting research issues can be: the role of specific cities in the global economy; the interindustrial relationships among 'global cities'; patterns in urban energy use and infrastructure; environmental impacts and techno-economic implications of implementing climate change mitigation measures; and cascaded economic damage of increasingly extensive extreme weather events from impacted city regions to other coupled urban economies.

Future research can focus on establishing and implementing a global cities I–O database. From a city green growth perspective, individuals or small research groups have utilized limited available IOTs at the city level to assess environmental implications of city growth and development. Thanks to available official statistics, researchers are able to calculate the direct and embodied carbon emissions, ecological footprints, and water consumption in some megacities in Australia, Japan, and China. Further, some governmental initiatives have also been made to collect energy and emission data to study environmental impact by world megacities, i.e. the C40 Cities Climate Leadership Group (C40) program (Betsill and Bulkeley, 2007; Rosenzweig et al., 2010). From a natural hazard adaptation perspective, researchers often derive city I–O models from national tables to estimate the indirect economic loss for hurricanes (e.g. Hallegatte, 2008), flooding (e.g. Steenge and Bočkarjova, 2007; Li et al., 2013), earthquakes (e.g. Rose et al., 1997; Okuyama, 2004), and terrorism (Santos and Haimes, 2004).

Those pioneer studies are useful to set up the foundation for constructing the global city I–O database. A one-stop project among the I–O community, perhaps similar to Global Trade Analysis Project (GTAP), or the WIOD project, may be required in order to coordinate the collection, compilation, validation, and construction processes. This can be potentially a ‘Big Data’ project and benefit from other data mining projects. In 25 years or less, we would be able to say: how much London’s economic growth is explained by power supply stability in Hohhot, the capital of Inner Mongolia, China; and what is the cascaded economic loss in Shanghai and San Paulo if London floods.

6. THE VIEWS OF MICHAEL L. LAHR: REGIONAL ACCOUNTS 25 YEARS LATER

Despite the passing of almost 30 years, much of Hewings and Jensen’s (1986, 1988) challenges and, hence, emerging trends for regional I–O analysis still hold. Perceived inaccuracies inherent to estimation techniques used to develop regional accounts continue to restrain certain applications and undoubtedly always will. Analysts appear secure that off-the-shelf regional I–O models are sufficiently accurate for regional economic impact analyses. This may be because the data entered as direct effects are deemed to be inherently less accurate than are the regional accounts used to produce the models. Meanwhile, the estimated accounts, which need not balance perfectly for such applications, may be insufficiently accurate to facilitate reasonable structural decomposition analyses – to examine the proximate causes of structural change in the regional economy.

Of course, the difference-maker between the qualities of national and regional accounts is data availability and the lack of trade barriers. (The lack of trade barriers within nations also tends to mean a lack of statistically viable interregional trade data.) It is my perception, however, that during the last 30 years, builders of regional accounts have been applying more regional data when building accounts. That is, rather than simply performing rows-only trade adjustments of national technology, analysts are now more frequently adjusting regional accounts so they incorporate a region’s difference from the national average for consumption patterns, public spending by the level of government, labor productivity, and effective taxation rates along the lines that I have made analytically explicit elsewhere

(Lahr, 2001a). In countries where interregional trade estimates are available, analysts are also incorporating them and are to some degree dispensing with location quotient and related techniques that estimate regional purchase coefficients, which have long been used to perform rows-only trade adjustments. The ever-decreasing price of computer power and internet data access, plus the availability of inexpensive software for matching and working with data from multiple sources has made it all possible.

It is not only that certain types of data series like those on interregional trade are unavailable at the subnational level. Indeed, it is just as often the case that data sets at the subnational level for industries are quite sparse due to disclosure issues – cases where one firm dominates a local industry or where three firms or less comprise the entire industry. Thus along with estimating interregional interindustry trade relationships (e.g. Jackson et al., 2006; Sargento et al., 2012), advancing techniques that fill-in such disclosure issues remains a key fixture in the development of regional accounts. Some of our colleagues have published rough outlines of the techniques that they apply (e.g. Gerking et al., 2001; Isserman and Westervelt, 2006). Others have done so using more sophisticated techniques (e.g. Holan et al., 2010; Rodrigues, 2013). My point is that ever more-accurate techniques for estimating missing data that are jointly expressed in spatial and sectoral hierarchies (e.g. employment data for the nation, state, and county and in terms of three-, four-, five-, and six-digit industry classifications) have and are being developed in the operations research field. In ways not envisioned by early producers of hybrid IOTs, we are now able to produce and incorporate a wide array of data much of it with very fine spatial and sectoral detail.

Techniques for adjusting IOTs in which selected data items are fixed have also been making the scene during the past 30 years. Such algorithms are important for national and regional accounts alike since perfect data systems truly never exist. Moreover, regional SAMs typically provide more known data items. Thus, balancing them requires more sophisticated balancing algorithms. Although some constrained balancing algorithms existed previously (e.g. Israilevich, 1986; Lahr, 2001b), one developed in Robinson et al. (2001) seems to mark a divide in the sophistication of them. That is, since that date the virtues of several other similarly purposed algorithms have been extolled. The relative merits and demerits of them remain unclear, particularly when processing time considerations are ignored. A working paper by Rodrigues (2012) promises that a set of theoretical tenets for identifying a best algorithm is on its way.

As foretold by Hewings and Jensen (1986, 1988), publications on integrated I–O models have been pillars of the methodological literature involving regional accounts. Then again, some bias is clearly at play here since the ever-productive Hewings has been a major contributor to the salient literatures (e.g. Hewings and Lee, 1983; Hewings, 1990; Israilevich et al., 1996, 1997; Marquez et al., 2003; Turner et al., 2012). Moreover, the topic of integrated models is where advances transcend the rather fuzzy regional–national boundary in I–O and related analyses. Almon (1966, 1991), Treyz et al. (1980), Kratena et al. (2013) and others have been advancing econometric/I–O linkages at the national–international level for some time. And the main issues that affect national computable general equilibrium (CGE) analyses remain critical, perhaps in spades, at the regional level. That is, closure rules, how the labor market is cleared, and the type of industrial organization and functional form applied to the industries' profit functions (perfect or imperfect competition) tend to make the largest differences in modeled outcomes (Mitra-Kahn, 2008; Cardenete et al., 2012). Of course, both regional CGE and econometric/I–O modeling, the availability of less data and the comparatively greater openness of the economies at the subnational level come into play. This makes such regional modeling even more challenging than its national equivalent. Of course, it also undoubtedly eliminates some possible applications as well.

Another area that has advanced considerably in a methodological dimension is multi-regional accounts. Many advances in such modeling are discussed elsewhere in this broader article with respect to balancing of reported international trade. But in addition to multi-regional tables composed of multiple national tables, interregional tables for composed regions within a single country (beyond those pre-existing in the USA and Japan) have arisen during the last couple of decades. Moreover, due to computational capacity, off-the-shelf models are now available, at least in the USA. Of course the trade flows generated for such models at very small areal levels typically remain unverified at this juncture.

A pervasive trend, as noted by Los (2011) during a recent presentation, is that publications on I–O analysis have been tilting increasingly toward content dominated by a policy orientation. The reasons for this are not perfectly clear, although that maturation of our science undoubtedly has something to do with it. Yes, as the frequency of conferences sponsored by the IIOA has increased, we purposely relabeled our conferences so that they exclude the word ‘Techniques’. But this was done to reflect who we were and not who we wanted the IIOA to be. In any case, for me, originating from the realm of regional science and working in a public policy school, the change in orientation has been a welcome one. Moreover, it has opened the way for interesting work with existing theoretical modeling systems – work on climate change, environmental emissions, energy use, water usage, so forth and so on. May it be fruitful and multiply.

7. THE VIEWS OF FERRAN SANCHO: BE FRUITFUL AND MULTIPLY

There is no doubt whatsoever in my mind that I–O analysis has become a field of knowledge and expertise all in itself. Despite its conceptual origin in economics and its data-oriented origin in national accounting statistics, I–O has been able to grow and develop (both!) along different avenues. From the theoretical contributions that underpinned Marxian and Ricardian models with a clear, well-understood conceptual architecture, to the empirical applications that provided governments with first-class information regarding the practical implementation of policies of many types – tax, environmental, regional, and labor-related policies, among others.

No wonder that Wassily Leontief’s contribution has transcended even its Nobel Prize status. The IIOA and the scholarly journal are doing well, as the continuing sequence of conferences and the significant impact factor of *ESR* attest. All this having been said, we need to reflect on a couple of things: where we are now and where we would might end up being when the I–O gold birthday for the Journal takes place, 25 years from now.

I will select and focus, by the acute pressure of the available real state, my comment on multiplier analysis. And with the readers’ permission I will use some items from my own research. As we all know, the Leontief inverse gives us a very valuable piece of information: you tell me where you would like to inject an extra unit of final demand, and I will be able to list each and every of the output repercussions across the whole economy. This is indeed a very remarkable economic fact that has endowed I–O analysis with a powerful and quite useful policy analysis tool. Think of the key sector methodologies, for instance, to appraise the full scope and analytical capacity behind the multiplier idea. Let me make a precision though. The Leontief inverse links final demand, in other words: net output, with gross output. Remember that within gross output we find the accumulated effects of all the chains of interactions after the initial injection has been processed throughout the economic system, round after round after round. Hence, the multiplier effect measures how extra *net* output ends up yielding additional *gross* output. We may wish to call this the 'net-to-gross' multiplier mapping.

The I–O methodology does not provide, directly, with easy ways to measure how net output yields net output, or how gross output gives rise to gross output. These are also quite legitimate, and policy-relevant, questions. Net output is certainly transformed into value-added, a measure of final output from the income generation perspective, but there is no actual creation of new net output, just a redistribution of the initial injected value (Sancho, 2013). Overall, the net output created is the net output injected, as a trivial inspection of the power expansion of the Leontief inverse quickly demonstrates. Using analogous notational conventions, we could call these complementary informational mappings as 'net-to-net' and 'gross-to-gross' multiplier mappings. The concept of 'net' multiplier, as proposed by Oosterhaven and Stelder (2002) and despite its name, aims at being a 'gross-to-gross' multiplier by way of compensating for the overvaluing that results from the use of the standard 'net-to-gross' multiplier. The appropriateness of this proposal has been hotly and thoroughly discussed (see De Mesnard, 2002, 2007a, 2007b; Dietzenbacher, 2005; Oosterhaven, 2007). In a recent paper, Sancho (2013) goes one step further and proves that the Oosterhaven and Stelder proposal is methodologically faulty. Their main theorem is seen to be incorrect, both conceptually and by way of numerical counterexample. Reinforcing De Mesnard's observation regarding instability, Sancho (2013) additionally proves that the 'net' multiplier notion does not correspond to a multiplier concept at all. First, nothing gets actually multiplied (see Proposition 4) and, second and even worse, a multiplicity Corollary shows that infinitely many technologies would give rise to the same apparent outcome, therefore invalidating any technological connection linking exogenous injections with endogenous outcomes.

A 'net-to-net' multiplier mapping requires more than what standard I–O provides. A possible way to proceed can be found using extended SAM models where repercussions from gross output adjustments reach back to increased final demands (i.e. net output) through additional income generation. It should therefore be possible, thanks to the extra and more complete general equilibrium layers, to net out the effects on net outputs. Another possibility is to go straight to CGE models and use a net output metric, such as GDP, either aggregate or sectorial since both can be counterfactually computed following an exogenous injection.

The 'gross-to-gross' multiplier mapping is certainly trickier to define. Recall the logic of the paradigmatic I–O model, whereby gross output is always endogenous. Under this circumstance, how can it be that an endogenous magnitude is simultaneously exogenous? From a causal, mathematical perspective, this simply cannot be. But what is mathematically unviable might nonetheless be economically countable, and provided we are careful not to use a causal interpretation, we would be just fine accountingwise. A first step would be to start from measuring direct and indirect requirements as in Parikh (1975), Milana (1985), Jeong (1982, 1984), Gim and Kim (1998), and more recently Sancho (2012).

Be as it may, multipliers constitute the conceptual heart of the I–O model, in all of its many versions: Leontief or Ghosh, simple or extended, quantity or price oriented, or even resource unrestricted versus restricted (Guerra and Sancho, 2012). This seminal concept has also been adopted and adapted by I–O spin-offs such as SAM and even CGE models (Cardenete and Sancho, 2012). It is a simple but wonderful idea which has yielded tremendous implications in I–O modeling. It is also an unquestionably useful tool for policy-makers and the applied fields. As scholars and practitioners we have benefited from it and so has society from the findings from its use and implementation. Our scholarly mission to be fruitful and multiply has been successful, and I anticipate that new developments will keep coming to give further strength and reputation to our profession.

8. THE VIEWS OF SANGWON SUH: INTERNATIONAL GOVERNANCE, SUPPLY-CHAIN LITERACY AND INFORMATION TECHNOLOGY ON THE FUTURE OF IOTS

How a scientific discipline will evolve is difficult to fathom. I just looked into the most recent issue of the *American Economic Review*. A paper there by (Bharadwaj et al., 2012) entitled ‘Early Life Health Interventions and Academic Achievement’ used large-scale longitudinal data and showed that children who received extra medical care at birth are likely to have higher grades in school later on. I wonder how many economists 25 years ago predicted that causal inference analyses will become a core business of their discipline later.

Nevertheless, I believe that how IOA distinguishes itself today will, to a certain extent, set a boundary of its future. I am sure that some of our ideas will evolve into something that does not even slightly resemble anything that we attribute IOA to today. But in that case, regardless of how great the idea is, it is unlikely to be classified as a part of IOA anyway. So with a reasonable certainty, I would argue that the future of IOA will share some of the criteria with which IOA distinguishes itself today.

What are such criteria? Krishnan (2009) identifies six criteria that are often used to distinguish an academic discipline: (1) common object of research (e.g. economic systems), (2) common body of knowledge (e.g. those in Miller and Blair, 2009), (3) common theory and concept (e.g. non-substitutability), (4) common terms and language (e.g. ‘commodity-technology model’), (5) common methods and tools (e.g. use of IOTs), and (6) institutional manifestation (e.g. the IIOA). Among them, the fifth criterion seems to be essential to IOA: it is hard to think of IOA that does not use an IOT.

So I would like to focus on the possible future of IOTs.

IOTs have evolved in the past. The introduction of the SNA and distinction of commodities and industries through the 1960s is one of the major innovations. What will be the future of IOTs?

I was fascinated to learn how Professor Leontief’s research group used punch-cards and a room-full computer to invert a several-dozens-by-several-dozens matrix overnight (Duchin, 2011). The development of information technology (IT) and the ability for modern computers to handle large amounts of data are truly remarkable. I believe that the developments in IT can greatly benefit the process of compiling IOTs including collecting, collating, analyzing, balancing, and transforming raw data into IOTs. Currently, compiling and releasing an IOT takes several years, by then the IOT has become obsolete for some applications. Researchers have used various updating techniques to make them look more current, but those are not comparable to official statistics.

Imagine that essential raw data for IOT-compilation are securely collected and processed in the course of normal operation of businesses, and the IOT is released soon after the New Year’s Day. Or what if IOTs are released on a quarterly or monthly basis with several thousand sectors and commodities in both physical and monetary units? What if each and every nation produces a globally harmonized IOT together with environmental extensions and international trade flows? What if IOTs become so granular, accurate, and current that production engineering and IOA become almost indistinguishable?

Well, such an IOT might be a dream to some IOA practitioners but a nightmare to, for example, Coca-Cola Company (Pendergrast, 1994). The increased ability to handle large amounts of data means nothing to IOT-complication unless the original source of data, i.e. industry, is willing to share its data. Furthermore, in the end, compilation of IOTs is one item – apparently an important one – in the long shopping list of a government or an institute, and if necessary the government or the institute can always choose to stop producing IOTs, which apparently happened in the past for some countries.

The problem is that both industry (data source) and government (sponsor) may not be strongly motivated to expand or improve on the current practice of compiling IOTs. I see two pathways that address this problem:

(1) International negotiations on cross-boundary environmental externalities such as climate change provide a strong motivation for international communities to mandate compilation of reliable environmental and economic accounts through, e.g. the SEEA
(2) Consumers' awareness on the environmental, natural resources, and social issues behind a product (called 'supply-chain literacy') leads industries to disclose their supply-chain information creating an international network of certified supply-chain data repository, which becomes *de facto* detailed, industry-supplied IOT.

I believe that we are already witnessing what might be the beginning of these new developments. International transfer or outsourcing of environmental externalities has been a topic that received a lot of attention recently, where IOTs have been instrumental (Peters et al., 2011; Lenzen et al., 2012). Consumption-based GHG accounts using multi-regional IOTs is frequently discussed in the IPCC.

Consumers, public and private alike, are demanding more information on how the supply chain is shaped when making a procurement decision. In response, companies are already disclosing substantial amount of data with their clients and the general public. Ecoinvent database (Ecoinvent Center, 2013), which is one of the largest public life cycle inventory database, for example, contains information on I–Os of over 3,000 processes in physical units. Over 4,000 companies are voluntarily disclosing their GHG emission figures through the CDP as of 2012.

I believe that these two lines of development, which are both already happening, will join the advances in IT in the confluence of new progresses in IOTs.

9. THE VIEWS OF CUIHONG YANG: THE VERY TIME FOR PRODUCING IOTS ON A YEARLY BASIS

IOA has been widely applied in economic, social, and environmental fields. One of the central problems of IOA, however, is that the compilation of survey-based IOTs is extremely time consuming and expensive. This implies that survey-based IOTs only become available with a serious time lag and are very often published only once every five years (for example, in China and Japan). This may seriously influence its applications, especially for emerging countries which are changing rapidly, like China. The long time lag of release has been one of the important reasons why I–O models have been criticized by some economists. In this respect, it is important to improve the timeliness of IOTs, mainly through the compilation of supply and use tables (SUTs).

9.1. Time Series of SUTs

A lot of countries have compiled annual SUTs as an integral part of the national accounts. Based on the System of National Accounts of 1993 (UN and others, 1993), SUTs are the statistical foundation of IOTs since the late 1990s. Examples include major EU countries, the USA, Canada, and Australia. Their statistical agencies are responsible for the compilation of SUTs (Lal, 2000; ABS, 2006; Eurostat, 2008; BEA, 2011). Annual SUTs may serve two purposes. On the one hand, they provide the basis for the compilation of annual IOTs. On the other hand, the national statistics may greatly benefit, since SUTs provide an ideal statistical framework to include the components of the production, income, and expenditure approaches to measuring GDP. This enables a coherent and balanced estimate of GDP both at current and constant prices.

At present, the WIOD project has collected and estimated a series of annual SUTs and IOTs for 1995–2009 for 40 countries (Dietzenbacher et al., 2013), which has become very popular and is widely cited. This database is a project-based outcome and its continuity is endangered if no new project is launched. It is therefore strongly suggested that statistical agencies undertake the production of SUTs on a yearly basis, using detailed statistics on production and consumption, and other related data. Researchers and practitioners can then make symmetric IOTs when necessary.

However, even if the compilation of SUTs becomes routine work by statistical agencies, several issues need to be further investigated. (i) The compilation methodology of SUTs under different basic statistical units, i.e. *establishments* or *enterprises*. In the case of *enterprises*, there is usually more than one activity involved and the share of this primary activity may be low (for example, around 70% in some Chinese enterprises) while the inputs for secondary activities are typically available at an aggregated level. It is thus more difficult to compile SUTs for enterprises. For countries employing establishments as basic units (such as the USA, some EU countries, Australia), yearly SUTs have been constructed and released regularly. For countries with enterprises as basic units, there are some preliminary studies to compile SUTs. For example, the National Bureau of Statistics of China tentatively constructed SUTs for 2005 and 2008 (Qi et al., 2011). (ii) Suitable models to convert SUTs into symmetric product-by-product or industry-by-industry IOTs based on appropriate technology assumptions. (iii) The integration of I–O models with econometric models and other time-series models to investigate structural changes in the economy.

Another hot issue in the following years of I–O will be global value chains, which are closely related to yearly SUTs and IOTs. Traditional trade statistics in terms of gross values give a distorted picture of trade imbalances between countries. Thus, it is important to estimate and release trade in value-added each year together with traditional trade statistics in order to obtain a clear view of global value chains.

9.2. Global Value Chains in the I–O Framework

Global value chains have been one of the hot topics in recent years in I–O. At this stage, we mainly focus on value-added, employment, environmental impacts generated by international trade and the slicing up of global value chains (for example, Chen et al., 2001, 2012; Dietzenbacher et al., 2012; Koopman et al., 2012; Timmer et al., 2013). Two kinds of IOTs have been discussed a lot: intercountry and single country IOTs. Several databases have been constructed or are under construction, including the Asian international IOTs (Inomata and Kuwamori, 2008; Meng et al., 2012), the WIOD database (Dietzenbacher et al., 2013), the OECD–WTO intercountry database (OECD–WTO, 2012), the Eora MRIO database (Lenzen et al., 2012) and the related UNCTAD TiVA dataset (Kanemoto and Rigo, 2013), and the GTAP database.[1] Based on the above data sets, there is plenty of literature related to global value chains. For single country IOTs, major efforts in terms of trade in value-added as well as trade in employment focused on I–O models capturing processing trade in China (Chen et al., 2001, 2012; Koopman et al., 2012).

Further research on this issue includes the following: (i) Methods to construct a time series of intercountry IOTs with a higher accuracy, integrating national accounts, and trade statistics. (ii) Separating processing trades both in single-country and intercountry IOTs. This applies to countries such as China, Mexico, and Indonesia, which have large shares of processing trade. (iii) The investigation of the position of a product or industry or even a country/region in global value chains. These researches may provide implications for industrial upgrading, centering on global value chains. This will be one of the major orientations to improve production efficiencies globally as well as the international competitiveness of a certain country/region.

For time series of SUTs and IOTs, it is crucial for national statistical agencies to become more involved both in I–O research (particularly the construction methodology of yearly SUTs) and the IIOA as well as national I–O associations.

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[1] GTAP, https://www.gtap.agecon.purdue.edu/databases/default.asp.

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